EXTENSION OF THE SYSTEMATIC APPROACH TO TROPICAL CYCLONE TRACK FORECASTING IN THE EASTERN AND CENTRAL NORTH PACIFIC

Mark A. Boothe-Civilian
B.S., University of California, Los Angeles, 1991
Master of Science in Meteorology-December 1997
Advisors: Russell L. Elsberry, Department of Meteorology
Lester E. Carr III, Department of Meteorology

This study extends an earlier study (White 1995) of the application of the systematic approach to tropical cyclone track forecasting of Carr and Elsberry to the eastern and central North Pacific, and contrasts these cases with those in the western North Pacific. The data sample is first expanded to seven years (1990-1996). Modifications to the environment structure conceptual models are: (i) introduction of two dominant ridge synoptic regions named Ridge Poleward and Ridge Equatorward based on the bowed orientation of the subtropical anticyclone; and (ii) combining the Weak Westerlies and Accelerating Westerlies into just one synoptic region called Midlatitude Westerlies. Only eight synoptic pattern/region combinations are needed to classify all of the 1,858 cases. Additions to the transitional mechanisms include: (i) the formation and dissipation of the mid-level low; (ii) monsoon trough formation; and (iii) orography. A new transition climatology reveals that a large fraction of transitions occur between the regions of the standard pattern. Subtropical Ridge Modulation and Vertical Wind Shear are determined to be the most important transitional mechanisms. Synoptic analysis sequences are provided to illustrate the synoptic pattern/regions and the primary transitions.

KEYWORDS: Tropical Cyclone Track Forecasting

DoD KEY TECHNOLOGY AREA: Battlespace Environments

COMPARISON OF LIDAR AND MINI-RAWINSONDE PROFILES

Daniel E. Harrison-Lieutenant Commander, United States Navy
B. S., United States Naval Academy, 1985
Master of Science in Meteorology and Physical Oceanography-June 1998
Advisors: Kenneth L. Davidson, Department of Meteorology
Carlyle H. Wash, Department of Meteorology

Current Light Detection and Ranging (LIDAR) technology allows for remotely sensed, real-time measurement of most atmospheric properties including structure, dynamics and primary chemical constituents. The LIDAR Atmospheric Profile Sensor (LAPS) instrument, completed in April 1996 at the Applied Research Laboratory/Pennsylvania State University (ARL/PSU), was developed as a prototype sensor for continuous, automated atmospheric soundings aboard aircraft carriers, advanced-radar combatants and shore stations. These data can then be used to calculate the atmospheric refractivity profiles for electromagnetic propagation prediction and as input to system performance assessments.

This report shows the advantages and disadvantages of LAPS atmospheric data as compared to the MRS sounders currently in use. LAPS can provide an accurate, continuous on-demand real-time data, is able to characterize variations in the marine boundary layer, and does not require cumbersome logistic support (e.g., helium bottles and balloons). The present weaknesses of LAPS are its relatively coarse vertical resolution, degraded daytime data due to scattering, sometimes erratic temperature measurements, and ship's gas absorption.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Lidar, Laps, Mini-rawinsonde, USNS Sumner (T-AGS 61)

SHIP OPERATING CHARACTERISTICS AND THEIR IMPLICATION FOR SHIPTRACK FORMATION

Scott D. Katz-Lieutenant Commander, United States Navy
B.S., University of Southern California, 1981
M.S., Duke University, 1983
Master of Science in Meteorology and Physical Oceanography-March 1998
Advisor: Phillip A. Durkee, Department of Meteorology
Second Reader: Carlyle H. Wash, Department of Meteorology

Shiptrack occurrence is restricted to a narrow range of environmental conditions and ship operating characteristics. Under environmental conditions favorable for shiptrack formation, not all vessels produce a track. Shiptrack producing diesel vessels are distinguished from non-shiptrack producing diesel vessels by a 17.7 percent higher rate of fuel use, 8.8 percent larger power plant size, and one knot higher transit speed. T-tests comparing these two populations indicate that power/transit speed, power*fuel/speed, power*fuel, tonnage/fuel use, power/hull cross-section, transit speed, power plant size, and rate of fuel use are tactically distinct (greater than 60% confidence level). These parameters and ratios of parameters may be useful in predicting the occurrence and non-occurrence of shiptracks.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Shiptrack, AVHRR, T-Test, Level of Significance

CALCULATING TROPICAL CYCLONE CRITICAL WIND RADII AND STORM SIZE USING NASA SCATTEROMETER WINDS

Scott G. Magnan-Captain, United States Air Force
B.S., State University of New York, Oneonta, 1990
Master of Science in Meteorology-March 1998
Advisors: Russell L. Elsberry, Department of Meteorology
Lester E. Carr, III, Department of Meteorology

Subjective and objective analyses of satellite scatterometer near-surface winds are utilized to estimate tropical cyclone (TC) critical wind radii and size over a region of the western North Pacific. An outer wind profile assuming a linear slope dependent on the TC latitude is used to determine the radial extent of cyclonic winds beyond a set radius. Inside the set radius, a partial conservation of angular momentum is assumed into the TC maximum wind radius and the 35-, 50-, and 100-kt radii are calculated. Nine TCs were investigated during the operating period of the NASA scatterometer (NSCAT). Critical wind radii in four quadrants (front, right, rear, and left) of the TCs are found to be comparable to the Joint Typhoon Warning Center (JTWC) critical wind radii values issued in warnings. The radial extent of cyclonic winds are also comparable to the radius of zero winds estimated by determining where the cyclonic flow turned to anticyclonic flow in the NSCAT sea-surface wind swaths.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Tropical Cyclone Wind Structure, NASA Scatterometer, Tropical Cyclonic Size

COMPARISON OF FLIR TACTICAL DECISION AIDS FOR INTER-SERVICE USE

Daniel E. Machado-Lieutenant Colonel, Venezuelan Army
B.S., Venezuelan Military University, 1990
Master of Science in Systems Engineering-September 1998
Advisors: Alfred W. Cooper, Department of Physics
Kenneth L. Davidson, Department of Meteorology

Electro-Optical Tactical Decision Aids (TDAs) have proven their utility as tools for range performance modeling and mission planning. However, several TDAs are in current use in the United States armed forces. In fact, the services use different TDA codes which differ in the input data files and their sources required, in the operator expertise required, and the hardware required to run the program.

Within the concept of Joint Operations, which has become crucial in the modern battlefield environment, all the services must share procedures, techniques, and often the same technology. This thesis presents a comparison between the Army FLIR TDA, (ACQUIRE), and the infrared module of the Navy/Air Force TDA, WinEOTDA. Differences in the modeling of underlying physical principles, input parameters, and predicted target detection ranges are presented. Despite differences in input and treatment of environmental effects this analysis indicates similar levels of accuracy for the two codes. For two scenarios selected average predictions for three "typical" sensors fall within 20% of published observations. With further analysis and an operational evaluation it may be possible to select one Electro-Optical Tactical Decision Aid for all branches of the military.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Tactical Decision Aids, ACQUIRE, WinEOTDA

COMPARISON OF THE NAVAL OPERATIONAL GLOBAL ATMOSPHERIC PREDICTION SYSTEM CLOUD ANALYSES AND FORECASTS WITH THE AIR FORCE REAL TIME NEPH ANALYSES CLOUD MODEL

Gary E. Marsteller-Captain, United States Air Force
B.S., Pennsylvania State University, 1992
Master of Science in Meteorology-June 1998
Advisor: Roger T. Williams, Department of Meteorology
Second Reader: Carlyle H. Wash, Department of Meteorology

This thesis compares RTNEPH and NOGAPS analyses for high, middle, and low clouds during January 1998 and October 1997. We believe that the RTNEPH analyses are reasonably accurate except for in the polar regions and the low clouds. NOGAPS forecasts at 12, 24, 36, and 48h are compared with the appropriate RTNEPH analyses. The difference fields averaged over a month show a rapid increase in the first 12 h over the forecast, followed by a slow growth to 48 h. The rapid increase is caused by model adjustment. The RTNEPH and NOGAPS (including forecasts) are separated into nine categories: clear, 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%. When the clear and 0-20% categories are combined the RTNEPH and NOGAPS analyses compare well for high and middle clouds. However the RTNEPH and NOGAPS analyses are distributed differently for the other categories, and the RTNEPH has many more occurrences for the cloudiest category (80-100%). For low clouds the RTINEPH and the NOGAPS are quite different, since the RTNEPH has difficulty analyzing clouds at night. The NOGAPS and the RTNEPH (except for low clouds) generally agree on the clear areas. However, it appears that NOGAPS underestimates the number of mostly cloudy cases and the distribution of categories is different.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Cloud Cover Analysis and Forecast

MICROWAVE OBSERVATIONS OF MESOSCALE CONVECTIVE SYSTEMS DURING TROPICAL CYCLONE GENESIS IN THE WESTERN NORTH PACIFIC

David Milot-Lieutenant, United States Navy
B.S., United States Naval Academy, 1989
Master of Science in Meteorology and Physical Oceanography-March 1998
Advisors: Russell L. Elsberry, Department of Meteorology
Patrick A. Harr, Department of Metorology

A better understanding of the role mesoscale convective systems (MCS) play in the genesis stages of tropical cyclones will increase the ability to predict their formation. This thesis studied polar-orbiter microwave and geostationary infrared satellite imagery to determine MCS structure and evolution during tropical cyclone genesis. Microwave imagery at frequencies of 19.35 GHz and 85.5 GHz were used to define convective and stratiform cloud areal amounts, percent coverage, and time-integrated rain rates. Collocations with geostationary infrared images are used to calibrate that imagery so that the hourly values may be calculated until another microwave image is available. Specifically, seven MCSs in two disturbances that eventually developed into tropical cyclones were analyzed. Two MCSs in non-developing storms are also described for contrast.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Mesoscale Convective Systems, Microwave Satellite Imagery, Tropical Cyclone Genesis, Formation

A COMPARISON OF THE NOGAPS AND GFDN DYNAMICAL TRACK PREDICTION MODELS DURING THE 1997 WESTERN NORTH PACIFIC TYPHOON SEASON

Robert G. Schnabel-Lieutenant, United States Navy
B.S., University of South Carolina, 1992
Master of Science in Meteorology and Physical Oceanography-March 1998
Advisors: Russell L. Elsberry, Department of Meteorology
Lester E. Carr III, Department of Meteorology

The performance of both the U.S. Navy (NOGAPS) and regional (GFDN) dynamical track prediction models during the 1997 western North Pacific typhoon season is documented. In the context of the Systematic Approach of Carr and Elsberry, a knowledge base of six conceptual models (summary in Table 8.1) is proposed that associates recurring tropical cyclone (TC) forecast track errors with various types of TC and environmental structures. Twenty-one storms of the 27 analyzed have periods in which at least one significant track error source was identified. More situations (23) were identified in the NOGAPS forecasts than in the GFDN forecasts (14). Individual case studies are presented to illustrate recurring scenarios with poor performance in either the NOGAPS model, GFDN model, or both. Use of these conceptual models and their supporting case studies may allow the JTWC forecaster to better understand how the NOGAPS model and GFDN model may perform in specified synoptic environments. It is hoped that the JTWC forecaster can use the information in this study to provide more accurate TC tracks by rejecting inappropriate model guidance during future typhoon seasons in the western North Pacific. In addition, this study may provide feedback to dynamical model producers as to situations in which large track errors have occurred, in hopes that the model might be improved in the future.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Tropical Cyclone Track Forecasting

REFRACTIVE CONDITION IN THE CARIBBEAN SEA AND ITS EFFECT ON RADAR SYSTEMS

Douglas F. Seijas-Lieutenant Colonel, Venezuelan Air Force
Master of Science in Systems Engineering-September 1998
Advisors: Kenneth L. Davidson, Department of Meteorology
David Jenn, Department of Electrical and Computer Engineering

Vertical gradients of pressure, temperature and humidity of the troposphere exert a strong influence over propagation of VHF, UHF, and SHF frequencies. These frequencies are associated with aircraft communications, radars and satellite communications, so it is important in military operations to collect precise and timely data from atmospheric conditions.

In this thesis programs from EREPS were used to assess refractive conditions in the Caribbean Sea against selected radar systems. Data given by SDS from radiosonde stations located in MS 43 and 44 were used as input for COVER and PROPR programs. Outputs from COVER are analyzed to find Optimal Altitude to Avoid Detection (OAAD) for a low-flying target. Outputs from PROPR using climatological data given by SDS and Optimal Altitude to Avoid Detection from COVER was used to verify OAAD against selected land- and ship-mounted radars operating in the Caribbean Sea. Finally, a system under development, TDROP is introduced in response to requirements for timely and exact data, in order to enhance the tactical data collection process.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Refractive Conditions, Air Defense, Radar Systems

LOW LATITUDE IONOSPHERIC EFFECTS ON RADIOWAVE PROPAGATION

Rasler W. Smith, DoD Civilian
B.S.E.E., University of Texas at Austin, 1979
M.S.E.E., Naval Postgraduate School, 1990
E.E., Naval Postgraduate School, 1990
Doctor of Philosophy in Electrical Engineering-June 1998
Advisor: Richard W. Adler, Department of Electrical and Computer Engineering
PhD Committee: Gus K. Lott, Department of Electrical and Computer Engineering
Jeffrey B. Knorr, Department of Electrical and Computer Engineering
Wilbur R. Vincent, Department of Electrical and Computer Engineering
David D. Cleary, Department of Physics
Kenneth L. Davidson, Department of Meteorology

This dissertation provides experimental observations and analyses that associate low-latitude transionospheric signal scintillation with transequatorial VHF radio propagation and errors in transionospheric geopositioning.

The experiment observed equatorial-region ionospheric total electron content (TEC) derived from Global Positioning System (GPS) signals using receivers on Oahu, Hawaii, Christmas Island, and Rarotonga, Cook Islands. The experiment simultaneously measured VHF transequatorial propagation of VHF television signals from Hawaii to Rarotonga.

Analysis shows that a moving second moment of vertical-equivalent TEC strongly correlates to each VHF transequatorial radio propagation event. From experimental observation analysis, the author develops models for prediction of TEP and time-space distribution of low-latitude transionospheric scintillation.

The author also develops equations that show the potential errors in time, frequency, and angle used in geopositioning solutions. These three parameters are potentially correctable using these techniques.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Low-Latitude, Ionosphere, Equatorial, Scintillation, Geopositioning, Global Positioning System, GPS, Total Electron Content, TEC, Transequatorial Propagation, TEP

A CASE STUDY OF THE MONTEREY BAY SEA BREEZE ON 25 AUGUST 1997

Steven M. Taylor-Civilian
B.S., Pennsylvania State University, 1992
Master of Science in Meteorology-September 1998
Advisors: Wendell A. Nuss, Department of Meteorology
Douglas K. Miller, Department of Meteorology

On 25 August 1997 a controlled burn on the former Fort Ord property raged out of control. The sea breeze was responsible for transporting the acrid smoke into the Salinas Valley. The PSU/NCAR mesoscale model, MM5, was run at 4 km grid resolution twice using two different PBL schemes (MRF and Burk-Thompson) and then verified by observations from several local mesoscale networks, including wind profiler data. The MM5 simulation was able to depict the 3-D structure of the sea breeze and differentiate between the local mountain-valley forcing and the large-scale sea breeze forcing. These two individual forcing mechanisms were responsible for an observed double surge in the time series of winds at Fort Ord. Further investigation is needed into the surface parameterization/land use tables to improve the surface forcing.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Meteorology)

KEYWORDS: Sea Breeze, Mesoscale Modeling, MM5 Simulations, Monterey Bay, Salinas Valley, Land Breeze

INTERACTIONS OF LARGE-SCALE TROPICAL MOTION SYSTEMS DURING THE 1996-1997 AUSTRALIAN MONSOON

Sylvia C. Taylor-Captain, United States Air Force
B.S., Pennsylvannia State University, 1991
Master of Science in Meteorology-September 1998
Advisor: Chih-Pei Chang, Department of Meteorology
Second Reader: Patrick A. Harr, Department of Meteorology

During the northern winter monsoon, several large-scale tropical motion systems are active in the southern tropical region of the ITCZ and SPCZ, including the maritime continent, northern Australia and the West Pacific. Superimposed on the mean state are transient large-scale systems including the Madden-Julian Oscillation (MJO) propagating from the equatorial Indian Ocean, the northeasterly cold surges from the northern hemisphere, and the easterly waves from the central or western Pacific. This work studied the possible interactions among these large-scale systems and their roles in the development of tropical cyclones. GMS water vapor data and NCEP reanalysis data during December 1996 to March 1997 were used. Examination of daily maps revealed that most of the TC development requires the interaction of two or more large-scale transient systems. The most frequent occurrences involved the interaction of the MJO and cold surges, followed by the interaction of the MJO and easterly waves.

DoD KEY TECHNOLOGY AREA: Other (Meteorology)

KEYWORDS: Australian Monsoon, Northern Winter Monsoon, Madden-Julian Oscillation, MJO, Tropical Cyclone, Cold Surge

STATISTICAL POST-PROCESSING OF NOGAPS TROPICAL CYCLONE TRACK FORECASTS

Greg A. Ulses-Lieutenant Commander, United States Navy
B.S., University of Washington, 1990
Master of Science in Meteorology and Physical Oceanography-March 1998
Advisor: Russell L. Elsberry, Department of Meteorology
Second Reader: Pat Harr, Department of Meteorology

A statistical post-processing technique is developed and tested to reduce the Navy global model (NOGAPS) track forecast errors for western North Pacific tropical cyclones during 1992-1996. In addition to the basic storm characteristics, the set of 42 predictors includes various track segments in the 00-72 h NOGAPS forecast as well as a 00-36 h backward extrapolation that is compared with the corresponding best-track positions. Although a NOGAPS forecast to at least 36 h is required to calculate the critical backward predictors, a reduced set of forward predictors that did not include the 48- and 72-h NOGAPS positions still produced the same improvement in track forecasts. Separate sets of statistical regressions are developed and tested for three subsets of the synoptic pattern/region combinations defined by Carr and Elsberry. For cyclones in the standard/dominant ridge combination, the improvement relative to NOGAPS is 61% after 12 h, and remains 8% after 72 h. For cyclones in the poleward/poleward-oriented pattern/region, the improvement over NOGAPS is 55% after 12 h, and 6% after 72 h. For a combination of cyclones in all remaining pattern/regions, the improvement relative to NOGAPS is 61% after 12 h, and 10% after 72 h. Comparison of these subsets with a single set of regression equations for all synoptic combinations showed no advantage obtained from using separate equation sets, so the single set is recommended. An independent test with all available 1997 NOGAPS forecasts decreased forecast track error by 50, 22, 12, 9, and 6% at 12, 24, 36, 48, and 72 h.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Tropical Cyclone Track Forecasting

RESPONSE OF THE SOUTH CHINA SEA TO FORCING BY TROPICAL CYCLONE ERNIE (1996)

Joseph M. Veneziano-Lieutenant Commander, United States Navy
B.S., University of Florida, 1987
Master of Science in Meteorology and Physical Oceanography-March 1998
Advisors: Peter C. Chu, Department of Oceanography
Michael J. Carron, Naval Oceanographic Office

The South China Sea (SCS) response to forcing by Tropical Cyclone Ernie (1996) was studied numerically using the Princeton Ocean Model (POM) with 20 km horizontal resolution and 23 sigma levels conforming to a realistic bottom topography. A fourteen-day experiment was conducted using a wind model that allowed for temporal variations of its translational speed, size and intensity. Restoring type salt and heat fluxes were used along with seasonal inflow/outflow at the open boundaries. The POM adequately simulated ocean responses to tropical cyclone forcing. Near-surface ocean responses simulated by the POM included strong asymmetrical divergent currents with near-inertial oscillations, significant sea surface temperature cooling, biased to the right of the storm track, and sea surface depressions in the wake of the storm. Subsurface responses included intense upwelling and cooling at the base of the mixed layer to the right of the storm track. Several unique features, caused by coastal interactions with storm forcing, were also simulated by the model. Along the coast of Luzon a sub-surface alongshore jet was formed, a warm anomaly off the northern tip of Luzon was significantly enhanced by surface layer convergence and storm surges simulated along the coasts of Luzon and Vietnam.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: South China Sea, Numerical Simulation, Tropical Cyclone Ernie (1996), Ocean Response to Tropical Cyclone Forcing

COMPARISON OF EVAPORATION DUCT HEIGHT MEASUREMENT METHODS AND THEIR IMPACT ON RADAR PROPAGATION ESTIMATES

John David Whalen-Lieutenant Commander, United States Navy
B. S., United States Naval Academy, 1985
Master of Science in Meteorology and Physical Oceanography-March 1998
Advisor: Kenneth L. Davidson, Department of Meteorology
Second Reader: Carlyle H. Wash, Department of Meteorology

A study was performed to compare shipboard measurements of atmospheric parameters that impact the evaporation duct and its effect on the propagation of electromagnetic energy from the AEGIS AN/SPY-1 radars. Two ships, *USS Anzio* and *USS Cape St. George*, participated in the annual NATO exercise, BALTOPS, during the summer of 1997. They were equipped with an automated METOC sensor system, developed by Johns Hopkins University Applied Physics Laboratory, called SEAWASP. SEAWASP provided continuous measurement of parameters determining near surface refractivity and the evaporative duct throughout the cruise. SEAWASP data were compared with manual bridge observations in order to illustrate the difference in propagation conditions assessed by the two methods. Additionally, ERS-1 Scatterometer wind data were used in conjunction with SEAWASP data to determine the feasibility of incorporating satellite wind data in determining evaporative duct heights. The automated SEAWASP data was able to depict, with greater accuracy, the constantly changing duct height conditions whereas the bridge observations, made at hourly intervals, lacked temporal resolution, thereby missing much of the variation in duct height. The discrepancies in duct heights between the two measurement systems led to differing propagation ranges resulting in shorter reaction times to counter threats to the ship.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Environmental Data, Radio Physical Optics, Radar Performance Prediction, Refraction, Evaporative Duct, Engineer's Refractive Effects Prediction System